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Abdominal obesity and cardiovascular disease risk factors within body mass index categories

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Abstract

Background

Several organizations recommend the use of measures of abdominal obesity in conjunction with body mass index (BMI) to assess obesity-related health risk. Recent evidence suggests that waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) are increasing within BMI categories. This shift may have affected the usefulness of abdominal obesity measures.

Data and methods

Data are from respondents aged 18 to 79 to the 2007 to 2009 Canadian Health Measures Survey. Using logistic regression, this paper examines cardiovascular disease (CVD) risk factors in relation to WC, WHR and WHtR ***within*** BMI health-risk categories. CVD risk factors considered include components of the metabolic syndrome.

Results

Among men in the normal and overweight BMI categories, WHR and WHtR were positively associated with having at least two CVD risk factors. All three abdominal obesity measures were associated with increased odds of having at least two CVD risk factors among normal-weight women. Abdominal obesity was not associated with CVD risk factors for people in obese class I.

Interpretation

Among men and women in the normal BMI category, measures of abdominal obesity are associated with increased odds of CVD risk factors. This underscores the importance of measuring and monitoring abdominal obesity in normal-weight men and women.

Keywords

Body composition, central obesity, metabolic syndrome, waist circumference, waist-to-height ratio, waist-to-hip ratio

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Elevated body mass index (BMI) is a well-established contributor to the aetiology of cardiovascular disease (CVD).[1] But while BMI is widely used to monitor the prevalence of obesity, it provides no information about the distribution of body fat. Some studies, have found that measures of abdominal obesity, principally, waist circumference (WC), waist-to-hip ratio (WHR), and more recently, waist-to-height ratio (WHtR), are more closely related to CVD morbidity and mortality than is BMI.[2-5] However, reviews of the literature conducted to assess which measure of adiposity is most strongly associated with CVD have yielded inconsistent conclusions.[2-4,6-11]

While a BMI classification system has been developed and used extensively to place adults in weight categories based on health risk,[1,12,13] a recent report by the World Health Organization concluded that, where possible, abdominal obesity should also be measured and used in conjunction with BMI to assess and predict disease risk.[14] Indeed, several organizations have recommended that a WC measure be used *within* BMI categories to classify obesity-related health risk.[1,12,13,15] Specifically, WC cut-points of 102 cm (40.2 inches) in men and 88 cm (34.6 inches) in women are used to denote high health risk within normal-weight, overweight, and obese BMI categories.

Recent evidence[16] suggests that the obesity phenotype among Canadians has changed over the past three decades—the distributions of WC, WHR and WHtR *within* BMI categories have shifted toward higher values.[17] This may have affected the degree to which measures of abdominal obesity are associated with CVD risk factors within BMI categories, particularly, normal-weight and obese.

For example, the percentage of normal-weight Canadian women at high health risk based on WC increased over the past three decades from almost nil to 3.8%.[17] Among people in obese class I, WC has increased to such an extent that almost all (84% of men and 94% of women) are now at high health risk according to WC.

Based on data from the 2007-2009 Canadian Health Measures Survey, this study examines associations between measures of abdominal obesity and CVD risk factors within the BMI categories for adults aged 18 to 79. The abdominal obesity measures considered are WC, WHR and WHtR. The CVD risk factors are components of the metabolic syndrome (a group of risk factors that predispose individuals to cardiovascular disease and type 2 diabetes): elevated blood pressure, elevated triglycerides, elevated glucose, and reduced high-density lipoprotein (HDL) cholesterol.

Methods

Data source

The Canadian Health Measures Survey (CHMS) is a nationally representative survey of the household population.[18-20] Data for cycle 1 were collected from March 2007 through February 2009 at 15 sites across the country for respondents aged 6 to 79. Full-time members of the Canadian Forces and residents of Crown lands, Indian reserves, institutions and certain remote regions were excluded. The sample represented approximately 96% of the population.[21]

The survey involved a household interview, during which information about socio-demographic characteristics, health and lifestyle was gathered, and a visit to a mobile examination centre where direct measurements (including body composition, blood pressure, and blood samples) were taken.

Of the households selected for the survey, 69.6% agreed to participate. In each responding household, one or two members were selected; 88.3% of selected household members completed the household interview, and 84.9% of the responding household members participated in the subsequent mobile examination centre component. The final response rate, adjusting for the sampling strategy, was 51.7%.[21]

Blood samples were collected at the mobile examination centre. Approximately half of respondents were selected at random to fast before blood samples were taken. Because some of the CVD risk factors considered in this study require fasting blood samples, it was necessary to base estimates on the subsample who fasted. The overall combined response rate for this subsample was 46.3%. Sampling weights for the fasted subsample were provided, which incorporated an adjustment for the probability of being selected into the subsample, a non-response adjustment (based on characteristics available for respondents versus non-respondents to this component of the survey), and calibration to ensure that estimates based on the weights were representative of the Canadian population by sex, age group and geographical region.[21]

This study pertains to respondents aged 18 to 79 who were part of the fasted subsample. Although the relationship between measures of adiposity and CVD risk factors is attenuated with advancing age, a significant association remains,[22] and therefore, the analyses included 65- to 79-year-olds. Pregnant women and respondents classified as underweight based on BMI (less than 18.5 kg/m^2) were excluded. Twelve records were dropped because of missing values for the anthropometric or CVD risk factor variables. This left 1,760 participants (846 men and 914 women).

Measures

Adiposity health risk variables

Weight was measured to the nearest 0.1 kg, and height, to the nearest 0.1 cm. Waist circumference (WC) was measured at the end of a normal expiration to the nearest 0.1 cm at the mid-point between the last floating rib and the top of the iliac crest.[1,23] Hip circumference was measured at the level of the symphysis pubis and the greatest gluteal protuberance.[23]

Body mass index (BMI) was calculated by dividing weight in kilograms (kg) by height in meters squared (m^2); waist-to-hip ratio (WHR), as WC in cm divided by hip circumference in cm; and waist-to-height ratio (WHtR), as WC in cm divided by height in cm.

Based on cut-points recommended by the World Health Organization,[1] Health Canada[12] and Obesity Canada,[13] the 1,760 CHMS respondents included in this analysis were divided into five health-risk categories based on BMI (kg/m^2):

- normal weight (18.5 to 24.9)
- overweight (25.0 to 29.9)
- obese class I (30.0 to 34.9)
- obese class II (35.0 to 39.9)
- obese class III (40.0 or more)

and three health-risk categories based on WC (cm):

- low risk (men, 93.9 or less; women, 79.9 or less),
- increased risk (men, 94.0 to 101.9; women, 80.0 to 87.9)
- high risk (men, 102.0 or more; women, 88.0 cm or more).

Respondents were also classified as being at increased/high risk based on WHR (men, 0.9 or more; women, 0.85 or more)[14] and WHtR (0.5 or more for both sexes).[6]

Sample sizes for the adiposity health risk variables are presented in Table 1.

CVD risk variables

The CVD risk factors are components of the metabolic syndrome based on the new harmonized definition.[24] This definition requires the presence of three or more of the following:

- elevated blood pressure (systolic 130 mmHg or more, or diastolic 85 mmHg or more)
- elevated triglycerides (1.7 mmol/L or more)
- reduced high-density lipoprotein (HDL) cholesterol (less than 1.0 mmol/L for men, and less than 1.3 mmol/L for women)
- elevated fasting blood glucose (5.6 mmol/L or more)
- abdominal obesity (WC 102 cm or more for men and 88 cm or more for women)

Table 1
Sample sizes for adiposity health risk variables, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Men	Women
Total	**846**	**914**
Body mass index		
Normal	265	394
Overweight	384	294
Obese class I	132	131
Obese class II or III	65	95
Waist circumference health risk		
Low	363	316
Increased	208	204
High	275	394
Waist-to-hip ratio health risk		
Low	274	519
Increased/High	572	395
Waist-to-height ratio health risk		
Low	235	359
Increased/High	611	555

Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Abdominal obesity was omitted, since the purpose of the study is to examine CVD risk factors in relation to abdominal obesity.

In addition to the measured values, respondents who reported taking specific CVD-related medications in the past month were considered to have the CVD risk factor. Respondents reported the Drug Identification Numbers (DIN) of all prescription medications they were taking. These were coded using the Anatomical Therapeutic Chemical (ATC) classification system.[25] The following ATC codes were used in defining the CVD risk factors:

- elevated blood pressure (all C02, all C03, C04AA02, C04AB01, all C07, all C08, all C09)
- elevated triglycerides (C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02, C10AX06)
- low HDL cholesterol (C04AC01, C04AC03, C10AB01, C10AB02, C10AB04, C10AB05, C10AC01, C10AC02, C10AX02)
- elevated fasting blood glucose (all A10 drugs)

A summary variable was constructed to identify respondents with at least two (of the four) CVD risk factors. Although the definition of the metabolic syndrome requires three factors, almost all respondents identified as having the metabolic syndrome (88%) had abdominal obesity (data not shown).

Control variables

Age was used as a continuous variable. Dichotomous variables were created for highest level of *education* (postsecondary graduation yes/no) and *smoking* status (current daily smoker yes/no). With self-reported data on *leisure-time physical activity*, a derived variable based on metabolic energy costs[26] was created to classify respondents as inactive versus active/moderately active. Three categories were used to describe *alcohol consumption*: *heavy drinker* (at least five drinks in one occasion on a weekly basis during the past year and/or heavy drinking in the previous week—15 or more drinks for men; 10 or more for women); *moderate/light drinker* (at least one drink in the past year); or *non-drinker* (did not drink in the past year). Use of *hormone replacement therapy* among women, was defined as taking prescription drugs in the past month with an ATC code G03.

Analysis

Descriptive statistics were used to profile the adiposity variables (means, standard deviations and correlations) and the CVD risk factors (percentages). With logistic regression models, the adiposity variables were examined in relation to CVD risk factors, controlling for age, education, smoking status, alcohol consumption, leisure-time physical activity, and for women, use of hormone replacement therapy. Because of high correlations among the adiposity variables, it was not possible to include them in the same regression models.

Regressions were first run using categorical variables based on health-risk cut-points for each adiposity variable. Regressions were then run using continuous measures for the adiposity variables (overall and within BMI categories). This second set of regressions was not run within the obese class II and III category because measures of abdominal obesity do not provide additional information about health risk for people with BMIs in this range.[12] To facilitate comparisons among the adiposity variables, the second set of regressions was also run based on standardized adiposity variables (the four adiposity variables were standardized to have a mean of 0 and a standard deviation of 1).

All analyses were weighted with the sampling weights for the fasted subsample in order to obtain estimates representative of the Canadian population. Statistical analyses were performed using SAS and SUDAAN software. Standard errors, coefficients of variation, and 95% confidence intervals were calculated with the bootstrap technique.[27,28] The number of degrees of freedom was specified as 11 to account for the CHMS sample design.[21] Significance levels were set at $p < 0.05$.

Results

Means and standard deviations for BMI and the three abdominal obesity variables (WC, WHR and WHtR) among people aged 18 to 79 are presented in Table 2. For both sexes, correlations among BMI, WC and WHtR were very high (r values greater than 0.9).

About one in four Canadians aged 18 to 79 had at least two CVD risk factors: 29% of men and 24% of women (Table 3).

Using logistic regression models, CVD risk factors were examined in relation to the health risk categories for the four adiposity variables (Table 4). Regardless of the variable, people in the increased/high health risk categories generally had higher odds of having CVD risk factors. The exception was WHtR, where the association did not attain statistical significance for elevated glucose (both sexes) or for elevated blood pressure (men). For BMI, a dose-response relationship emerged: people

Table 2
Descriptive statistics for adiposity variables, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Body mass index (kg/m^2)			Waist circumference (cm)			Waist-to-hip ratio (%)			Waist-to-height ratio (%)		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Men												
Mean	27.3	26.8	27.8	95.0	93.4	96.6	92.0	91.3	92.8	54.1	53.3	55.0
Standard deviation	4.8	...	...	13.9	...	...	7.9	...	...	8.1	...	...
Correlations												
Body mass index (kg/m^2)	...	...	...	0.92	...	...	0.62	...	...	0.91	...	...
Waist circumference (cm)	...	...	...	...	...	...	0.82	...	...	0.96	...	...
Waist-to-hip ratio	...	...	...	...	...	...	...	...	...	0.84	...	...
Women												
Mean	26.8	25.9	27.7	87.2	84.7	89.7	83.0	82.0	84.0	53.8	52.3	55.2
Standard deviation	5.9	...	...	15.3	...	...	8.0	...	...	9.7	...	...
Correlations												
Body mass index (kg/m^2)	...	...	...	0.91	...	...	0.55	...	...	0.92	...	...
Waist circumference (cm)	...	...	...	...	...	...	0.79	...	...	0.97	...	...
Waist-to-hip ratio	...	...	...	...	...	...	...	...	...	0.79	...	...

... not applicable
Note: Excludes respondents classified as underweight based on body mass index (less than 18.5).
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Table 3
Prevalence of cardiovascular disease (CVD) risk factors, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Elevated blood pressure			Elevated triglycerides			Elevated glucose			Reduced HDL cholesterol			At least two CVD risk factors		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Men															
Overall[†] (%)	28.0	24.1	32.2	28.8	22.5	35.9	19.6	16.4	23.2	24.5	19.4	30.6	29.1	25.9	32.5
Based on lab measurement only	17.0	13.5	21.3	28.5	22.4	35.6	19.1	16.1	22.7	24.2	18.9	30.4	...	...	...
Based on medication use only	14.4	12.6	16.3	F	...	...	2.0	1.4	2.7	F	...	...	...	...	...
Sample size with risk factor[†]	292	...	...	249	...	...	207	...	...	203	...	...	302	...	...
Women															
Overall[†] (%)	24.9	21.1	29.1	20.1	15.7	25.3	13.0	10.1	16.6	36.8	28.5	45.9	23.9	20.1	28.2
Based on lab measurement only	13.2	9.6	17.9	20.0	15.6	25.2	12.4	9.6	15.9	36.5	28.1	45.8	...	...	...
Based on medication use only	17.5	15.3	20.0	F	...	...	3.2[E]	1.8	5.4	F	...	...	...	...	...
Sample size with risk factor[†]	261	...	...	193	...	...	138	...	...	314	...	...	238	...	...

† based on lab measurement/medication use
... not applicable
E use with caution
F too unreliable to be published
Note: Excludes respondents classified as underweight (body mass index less than 18.5).
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

Table 4
Adjusted odds ratios relating adiposity health risk variables to cardiovascular disease (CVD) risk factors, by sex, household population aged 18 to 79 years, Canada, 2007-2009

	Elevated blood pressure			Elevated triglycerides			Elevated glucose			Reduced HDL cholesterol			At least two CVD risk factors		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to	Estimate	from	to
Men															
Body mass index category															
Normal†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Overweight	1.6	0.8	3.3	3.4*	2.0	5.9	1.4	0.7	2.7	4.8*	2.0	11.4	3.9*	1.9	8.1
Obese class I	2.0	0.7	5.8	5.5*	2.4	12.8	4.3*	1.6	11.4	6.4*	2.0	19.8	9.2*	3.7	22.9
Obese class II or III	8.4*	3.3	21.8	5.5*	1.4	21.7	5.9*	2.1	16.6	7.2*	2.5	20.3	17.5*	5.1	59.9
Waist circumference health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased	2.2*	1.2	4.0	2.6*	1.1	5.9	1.6	0.7	3.7	2.4	0.9	6.5	3.6*	1.9	6.8
High	3.6*	1.7	7.7	3.8*	1.7	8.5	2.4*	1.3	4.6	3.8*	1.7	8.2	6.4*	2.9	13.7
Waist-to-hip ratio health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased/High	2.6*	1.3	5.2	4.3*	1.8	10.1	2.3*	1.1	5.1	2.9*	1.3	6.7	5.2*	2.7	9.8
Waist-to-height ratio health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased/High	2.0	0.9	4.5	7.9*	2.0	30.8	1.9	0.8	4.6	5.7*	2.3	14.0	13.0*	4.9	34.2
Women															
Body mass index category															
Normal†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Overweight	2.0*	1.1	3.6	4.0*	1.9	8.7	0.9	0.3	3.2	2.9*	1.6	5.2	2.9*	1.4	6.2
Obese class I	3.0*	1.2	7.5	8.2*	4.1	16.4	4.8*	1.4	17.0	5.0*	3.2	7.8	9.9*	3.5	28.1
Obese class II or III	5.6*	2.2	14.5	7.9*	2.9	21.5	3.7*	1.4	10.1	8.9*	4.2	18.9	13.3*	4.3	40.9
Waist circumference health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased	2.8*	1.1	7.4	2.9	1.0	8.7	1.4	0.6	3.3	2.5*	1.0	6.1	3.9*	1.8	8.2
High	3.7*	1.6	8.5	9.4*	3.5	25.8	3.7*	1.6	8.7	4.7*	2.7	8.2	13.8*	6.6	28.8
Waist-to-hip ratio health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased/High	2.3*	1.3	4.0	5.9*	2.3	15.1	4.6*	2.2	9.4	3.3*	1.9	5.8	6.0*	3.3	11.0
Waist-to-height ratio health risk															
Low†	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...	1.0	...	...
Increased/High	2.7*	1.3	5.8	7.8*	3.5	17.5	3.4	0.9	12.3	3.9*	2.3	6.7	11.8*	4.9	28.4

† reference category
* significantly different from reference category ($p<0.05$)
Notes: Excludes respondents classified as underweight (body mass index less than 18.5). Adjusted for age, education, smoking status, alcohol consumption, physical activity level and hormone replacement use (women). Separate models were run for each adiposity variable.
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

in the combined obese class II and III category had considerably higher odds (17.5 for men and 13.3 for women) of having at least two CVD risk factors than did those in the normal-weight category.

Based on continuous measures, all four adiposity variables were strongly associated with having at least two CVD risk factors (Table 5). For example, on average, among both men and women, each 1 cm increase in WC was associated with a 1.07 increase in the odds of having at least two CVD risk factors.

To facilitate comparisons, regressions were also run based on standardized adiposity variables. A one-standard-deviation-increase in BMI (4.8 kg/m^2 for men; 5.9 kg/m^2 for women) was, on average, associated with a 2.40 increase in the odds of having at least two CVD risk factors for men, and a 2.56 increase for women. Based on standardized variables, the odds ratios for the three abdominal obesity measures were slightly higher than those for BMI (WC: 2.63 for men and 2.97 for women; WHR: 2.80 for men and 2.64 for women; WHtR: 2.85 for men and 3.21 for women), although the confidence intervals of the four variables overlapped for both sexes.

Table 5
Adjusted odds ratios relating adiposity variables to having at least two cardiovascular disease (CVD) risk factors, by sex and BMI category, household population aged 18 to 79 years, Canada, 2007-2009

	At least two CVD risk factors			At least two CVD risk factors (standardized adiposity variables)		
	Adjusted odds ratios	95% confidence interval from	95% confidence interval to	Adjusted odds ratios	95% confidence interval from	95% confidence interval to
Men						
Total†						
Body mass index (kg/m²)	1.20*	1.12	1.29	2.40*	1.71	3.37
Waist circumference (cm)	1.07*	1.05	1.10	2.63*	1.93	3.60
Waist-to-hip ratio (%)	1.14*	1.10	1.18	2.80*	2.08	3.76
Waist-to-height ratio (%)	1.14*	1.09	1.19	2.85*	2.04	3.99
Normal weight						
Body mass index (kg/m²)	1.38	0.71	2.68	1.70	0.57	5.12
Waist circumference (cm)	1.06	0.98	1.15	1.56	0.87	2.82
Waist-to-hip ratio (%)	1.18*	1.06	1.32	2.98*	1.45	6.12
Waist-to-height ratio (%)	1.22*	1.01	1.49	2.38*	1.02	5.55
Overweight						
Body mass index (kg/m²)	1.39*	1.02	1.90	1.63*	1.03	2.57
Waist circumference (cm)	1.09	1.00	1.18	1.71	1.00	2.94
Waist-to-hip ratio (%)	1.10*	1.05	1.15	1.74*	1.32	2.29
Waist-to-height ratio (%)	1.19*	1.09	1.30	1.96*	1.41	2.72
Obese class I						
Body mass index (kg/m²)	0.87	0.55	1.35	0.82	0.44	1.52
Waist circumference (cm)	0.92	0.84	1.02	0.65	0.39	1.09
Waist-to-hip ratio (%)	0.98	0.81	1.17	0.90	0.40	2.04
Waist-to-height ratio (%)	1.02	0.78	1.33	1.07	0.44	2.61
Women						
Total†						
Body mass index (kg/m²)	1.17*	1.10	1.25	2.56*	1.74	3.76
Waist circumference (cm)	1.07*	1.05	1.09	2.97*	2.23	3.95
Waist-to-hip ratio (%)	1.13*	1.08	1.18	2.64*	1.89	3.69
Waist-to-height ratio (%)	1.13*	1.09	1.17	3.21*	2.33	4.43
Normal weight						
Body mass index (kg/m²)	1.51*	1.04	2.20	2.05*	1.07	3.92
Waist circumference (cm)	1.15*	1.03	1.30	2.68*	1.20	6.00
Waist-to-hip ratio (%)	1.19*	1.01	1.40	2.87*	1.06	7.74
Waist-to-height ratio (%)	1.30*	1.05	1.61	2.90*	1.21	6.93
Overweight						
Body mass index (kg/m²)	1.10	0.81	1.48	1.14	0.74	1.76
Waist circumference (cm)	1.04	0.98	1.11	1.36	0.86	2.14
Waist-to-hip ratio (%)	1.07	0.99	1.15	1.59	0.96	2.65
Waist-to-height ratio (%)	1.11	0.99	1.23	1.60	0.96	2.66
Obese class I						
Body mass index (kg/m²)	0.79	0.42	1.49	0.74	0.33	1.67
Waist circumference (cm)	1.01	0.89	1.15	1.08	0.40	2.89
Waist-to-hip ratio (%)	1.05	0.90	1.23	1.45	0.45	4.65
Waist-to-height ratio (%)	1.06	0.87	1.28	1.33	0.51	3.47

† excludes respondents classified as underweight (body mass index less than 18.5)
* significantly different from 1.0 ($p<0.05$)
Notes: Adjusted for age, education, smoking status, alcohol consumption, physical activity level and hormone replacement use (women). Adiposity variables were entered into regression models as continuous variables. Separate models were run for each adiposity variable.
Source: 2007-2009 Canadian Health Measures Survey (fasted sample).

What is already known on this subject?

- Elevated body mass index (BMI) and abdominal obesity are associated with increased risk of cardiovascular disease.
- Several health organizations recommend the use of measures of waist circumference within BMI categories to assess obesity-related health risk, but reviews of the literature to determine which adiposity measure is most strongly associated with CVD have yielded inconsistent conclusions.
- A Canadian study based on data collected 20 years ago found that higher waist circumference (WC) was associated with increased prevalence of CVD risk factors among women in the overweight and obese class I categories; among men, WC was not associated with increased prevalence of CVD risk factors in any BMI category.
- For a given BMI, Canadians have higher measures of abdominal obesity than they did 30 years ago.

What does this study add?

- Among men in the normal-weight and overweight categories, waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were associated with increased odds of CVD risk factors.
- Among women in the normal-weight category, WC, WHR, and WHtR were associated with increased odds of CVD risk factors.
- For men and women in obese class I, measures of abdominal obesity were not associated with increased odds of CVD risk factors.

When the odds of having at least two CVD risk factors were examined *within* BMI categories, significant associations were observed for WHR and WHtR among men in the normal-weight (2.98 for WHR and 2.38 for WHtR based on standardized variables) and overweight (1.74 for WHR and 1.96 for WHtR based on standardized variables) categories. The odds (1.71) for WC approached significance (p=0.06) for overweight men. For men in obese class I, none of the adiposity variables was associated with having at least two CVD risk factors.

Among normal-weight women, all three abdominal obesity variables and BMI were associated with increased odds of having at least two CVD risk factors (2.68 for WC, 2.87 for WHR, 2.90 for WHtR, and 2.05 for BMI based on standardized variables). But among women in the overweight and obese class I categories, none of the variables was associated with having at least two CVD risk factors, although the odds approached significance (p=0.07) for WHR (1.59) and WHtR (1.60) among women who were overweight.

Discussion

Based on nationally representative data, the results of this study provide evidence that measures of BMI and abdominal obesity are associated with increased prevalence of CVD risk factors. Moreover, *within* certain BMI categories, measures of abdominal obesity are associated with an increased risk of having at least two CVD risk factors. Among normal-weight and overweight men, WHR and WHtR were associated with CVD risk factors. Among normal-weight women, all three measures of abdominal obesity were related to CVD risk factors. However, among overweight women, none of the abdominal obesity measures was significantly related to CVD risk factors, although associations with WHR and WHtR approached significance. Among men and women in obese class I, measures of abdominal obesity were not associated with CVD risk factors.

A study based on data from the Canada Heart Health Surveys (1986 to 1992), which had a design and approach similar to the present analysis, found that among women, but not men, in the overweight and obese class I categories, elevated WC was associated with increases in CVD risk factors.[29] This earlier study excluded normal-weight people because of the small number who had a large WC, and did not assess WHtR and WHR. An American analysis of data from the Third National Health and Examination Survey (1988 to 1994) found that elevated WC was associated with increased CVD risk factors among women in the normal, overweight and obese class I categories, and among men in the overweight and obese class I categories.[30]

Differences between the results of the current analysis and these earlier studies may, in part, reflect recent changes in the obesity phenotype in Canada[16] and other countries.[31,32] Larger increases in WC than in BMI resulted in a shift toward higher WC values *within* BMI categories.[17] Almost all men and women in obese class I are now at high health risk based on WC, as are the majority of overweight women (more than a threefold increase since 1981).[17] The finding that WC (as a continuous variable) within these sex-BMI categories was not associated with increases in CVD risk factors suggests that WC measures may no longer be useful in assessing CVD risk within these sex-BMI categories. Whether this is true for other obesity-related health risks is unclear.

In the earlier Canadian study,[29] sample size was insufficient to consider WC among normal-weight women. However, by 2007-2009, close to one-quarter of normal-weight women were classified at increased/high health risk based on their WC,[17] and results from the current study show that WC is now associated with increases in CVD risk factors for normal-weight women.

Elevated odds of CVD risk factors were observed for WC among normal-weight and overweight men, but associations did not attain statistical significance. However, in these BMI categories, WHR and WHtR were significantly associated with CVD risk factors. As well, for women in the normal-weight and overweight BMI categories, based on the standardized coefficients, the odds ratios for WHR and WHtR were higher than for WC, although the confidence intervals overlapped. Among overweight women, associations with CVD risk factors for WHR and WHtR approached significance.

The INTERHEART case-control study, which had the benefit of a very large sample size (12,000 myocardial infarction cases and 15,000 controls), found that the risk of myocardial infarction was more strongly associated with WHR than with WC.[5] It was suggested that the advantage of WHR over WC in assessing health risk is due to the protective effect of larger hip circumference.[5] Other studies have found independent associations between WC (positive) and hip circumference (negative) with obesity-related diseases and mortality.[33-35] However, the value of WHR in clinical practice is limited because of difficulties in interpretation—is an individual's risk greater because of a high WC and/or a low hip circumference? Furthermore, loss in abdominal fat due to weight reduction will not be reflected in changes in WHR (both WC and hip circumference will decrease), making WHR an inadequate tool for use in weight loss management.[36] Finally, contrary to the findings of the INTERHEART case-control study, a recent meta-analysis of 58 cohort studies concluded that BMI, WC and WHR had similar strengths of association with CVD risk.[37]

Associations between WHtR and health outcomes have been studied less extensively. A systematic review of the literature examining associations with CVD and diabetes concluded that WHtR is an effective screening tool in assessing health risk, probably better than WC.[6] This may be due to the protective effect of height.[38]

Canadian clinical practice guidelines recommend that to monitor and assess obesity-related health risks among adults, WC should be measured in addition to

BMI.[13] But because of the complexity of collecting measures of abdominal obesity, most large population-based surveys conducted by Statistics Canada rely exclusively on BMI. The strong gradient observed in CVD risk factors by BMI category in the current study supports this practice. Although it would be useful to routinely collect measures of abdominal obesity in addition to BMI, the high correlation between BMI and WC (more than 0.9) in this study suggests that BMI is an excellent proxy in assessing obesity-related CVD risk when it is not feasible to measure abdominal obesity.

Limitations

Important limitations of this study include the response rate, the size of the fasting subsample, restrictions on the availability and number of control variables in the analysis, the cross-sectional design of the study, and the inherent limitations of the accepted thresholds for increased health risk associated with each indicator.

The fasting subsample response rate was 46.3%. Although sampling weights were adjusted to compensate for all four levels of non-response (household roster, household interview, mobile examination center visit, and fasting blood sample), estimates may be biased if individuals with certain characteristics were less likely to participate. The degree to which this may have affected associations with CVD risk factors is unknown. Nonetheless, a study that examined whether the characteristics of those who responded to the household questionnaire differ from the characteristics of those who completed the mobile examination component found no significant differences in estimates when the non-response adjustment was applied.[21]

The relatively small fasting sample size and the clustered nature of the sample design resulted in fairly wide confidence intervals for the odds ratios relating obesity measures to CVD risk factors. Larger sample sizes would improve the ability to compare the effectiveness of risk assessment among the various adiposity measures. As well, the limited sample size prevented examination of categorical abdominal obesity variables (based on health risk) in relation to CVD risk factors *within* BMI categories.

In the regression models examining adiposity variables in relation to CVD risk factors, a maximum of 10 control variables could be entered because of the 11 degrees of freedom available in the CHMS sample design. In supplementary analyses that considered ethnicity and family history of CVD as potential confounders, associations between the adiposity variables and CVD risk factors were not altered.

Although it was not possible to control for women's menopause status (such information was not included in the CHMS), this is addressed to some extent by the inclusion of age, which is correlated with menopause.

The cross-sectional nature of the CHMS precludes an assessment of the temporal ordering of excess weight and the onset of CVD risk factors.

Finally, the results of this study cannot be generalized to other health outcomes such as heart disease, stroke and diabetes.

Conclusion

The current analysis indicates that BMI is associated with increases in CVD risk factors, and therefore, can be used to measure obesity-related health risk in the context of population-based surveys. The study also supports the Canadian clinical practice guideline that, in addition to BMI, WC should be measured to assess obesity-related health risk in adults.[13] Unlike past research based on Canadian data,[29] this analysis found that measures of abdominal obesity were associated with increased risk for overweight men, and for normal-weight men and women, who, based on their BMI, are not considered to be at elevated risk of obesity-related disease. As more cycles of CHMS data are collected and sample sizes increase, future research will be able to compare the relative usefulness of WC, WHR and WHtR within BMI categories in identifying additional health risk. ■

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